APPENDIX E
SEDIMENT CONTRIBUTION FROM HILLSLOPE EROSION

Introduction

Upland sediment loading due to hillslope erosion was modeled using the USLE, and sediment delivery to the stream was predicted using a sediment delivery ratio. This model provided an assessment of existing sediment loading from upland sources and an assessment of potential sediment loading through the application of BMPs. For this evaluation the primary BMP evaluated includes the modification in upland management practices. When reviewing the results of the upland sediment load model it is important to note that a significant portion of the remaining sediment loads after BMPs in areas with grazing and/or silvicultural land-uses is also a component of the "natural upland load." However, the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

A list of land cover classifications used in the USLE model is presented in **Table E-1**, along with a description of which land-use was associated with each cover type for the purposes of sediment source assessment and load allocations.

Table E-1. Land Cover Classifications for the USLE Model.

Land Cover Classifications	Land-use / Sediment Source
Bare Rock/Sand/Clay	Natural Source
Deciduous Forest	Natural Source
Evergreen Forest	Natural Source
Logging	Silviculture
Grasslands/Herbaceous	Grazing
Shrubland	Grazing
Pasture/Hay	Cropland
Fallow	Cropland
Small Grains	Cropland

Universal Soil Loss Equation (USLE)

The general form of the USLE has been widely used for erosion prediction in the U.S. and is presented in the National Engineering Handbook (1983) as:

(1) $A = RK(LS)CP$ (in tons acre^{-1} year^{-1})

where soil loss (A) is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice factor (P) (Wischmeier and Smith 1978, Renard et al. 1991). The USLE estimates average soil loss from sheet and rill erosion, but does not estimate soil loss from gully erosion. USLE was selected for the Shields River watershed due to its relative simplicity, ease in parameterization, and the fact that it has been integrated into a number of other erosion prediction models. These include: (1) The Agricultural Nonpoint Source Model (AGNPS), (2) Areal Nonpoint Source Watershed Environment Response Simulation Model (ANSWERS), (3) Erosion Productivity Impact Calculator (EPIC), (4) Generalized Watershed Loading Functions (GWLF), and (5) the Soil Water Assessment Tool (SWAT) (Doe et. al. 1999). A detailed description of the general USLE model parameters is presented below.

The **R-factor** is an index that characterizes the effect of raindrop impact and rate of runoff associated with a rainstorm. It is a summation of the individual storm products of the kinetic energy in rainfall (hundreds of ft-tons acre-1 year-1) and the maximum 30-minute rainfall intensity (inches hour-1). The total kinetic energy of a storm is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period.

The **K-factor** or soil erodibility factor indicates the susceptibility of soil to resist erosion. It is derived by measurement of soil particle size (texture), percent organic matter, structure, and permeability. It is a measure of the average soil loss (tons acre-1 hundreds of ft-tons-1 per acre of rainfall intensity) from a particular soil in continuous fallow. The K-factor is based on experimental data from the standard SCS erosion plot that is 72.6 ft long with uniform slope of 9%.

The **LS-factor** is a function of the slope and overland flow length of the eroding slope or cell. For the purpose of computing the LS-value, slope is defined as the average land surface gradient. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. According to McCuen et. al. (1998), flow lengths are seldom greater that 400 or shorter than 20 feet.

The **C-factor** or crop management factor is the ratio of the soil eroded from a specific type of cover to that from a clean-tilled fallow under identical slope and rainfall. It integrates a number of factors that effect erosion including vegetative cover, plant litter, soil surface, and land management. The original C-factor of the USLE was experimentally determined for agricultural crops and has since been modified to include rangeland and forested cover. It is now referred to as the vegetation management factor (VM) for non-agricultural settings (Brooks et. al. 1997).

Three different kinds of effects are considered in determination of the VM-factor. These include: (1) Canopy cover effects; (2) effects of low-growing vegetal cover, mulch, and litter; and (3) rooting structure. A set of metrics has been published by the Soil Conservation Service (SCS) for estimation of the VM-factors for grazed and undisturbed woodlands, permanent pasture, rangeland, and idle land. Although these are quite helpful for the Shields River watershed, Brooks et. al. (1997) cautions that more work has been carried out in determining the agriculturally based C-factors than rangeland/forest VM-factors. Because of this, the results of the interpretation should be used with discretion.

The **P-factor** (conservation practice factor) is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing, and contouring and is applicable only to agricultural lands. Values of the P-factor compare straight-row (up-slope down-slope) farming practices with that of certain agriculturally-based conservation practices.

Modeling Approach
Sediment delivery from hillslope erosion was estimated using a USLE based model to predict soil loss, along with a sediment delivery ratio (SDR) to predict sediment delivered to the stream. This USLE based model is implemented as a watershed scale, grid format, GIS model using ArcView v 9.0 GIS software.

Desired results from the modeling effort include the following: (1) Annual sediment load from each of the water quality limited segments on the state's 303(d) List and (2) the mean annual source distribution from each land category type. Based on these considerations, a GIS-modeling approach (USLE 3-D) was formulated to facilitate database development and manipulation, provide spatially explicit output, and supply output display for the modeling effort.

Modeling Scenarios
Two upland management scenarios were proposed as part of the Shields River modeling project. They include: (1) An existing condition scenario that considers the current land use cover and management practices in the watershed and (2) an improved grazing and cover management scenario.

Erosion was differentiated into two source categories for each scenario: (1) Natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. A similar classification is presented as part of the National Engineering Handbook Chapter 3 - Sedimentation (USDA, 1983). Differentiation is necessary for TMDL planning.

Data Sources
The USLE-3D model was parameterized using a number of published data sources. These include information from (1) USGS, (2) Spatial Climate Analysis Service (SCAS), and (3) Soil Conservation Service (SCS). Additionally, local information regarding specific land use management and cropping practices was acquired from the Montana Agricultural Extension Service (MAES) and the NRCS. Specific GIS coverages used in the modeling effort included the following:

R – Rainfall factor. Grid data of this factor was obtained from the NRCS and is based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. PRISM precipitation data is derived from weather station precipitation records, interpolated to a gridded landscape coverage by a method (developed by the Spatial Climate Analysis Service of Oregon State University) which accounts for the effects of elevation on precipitation patterns.

K – Soil erodibility factor. Polygon data of this factor were obtained from the NRCS General Soil Map (STATSGO) database. The USLE K factor is a standard component of the STATSGO soil survey. STATSGO soils polygon data were summarized and interpolated to grid format for this analysis.

LS – Slope length and slope factors. These factors were derived from 30m USGS digital elevation model (DEM) grid data, interpolated to a 10m pixel.

C – Cropping factor. This factor was estimated using the National Land Cover Dataset (NLCD), using C-factor interpretations provided by the NRCS and refined by Montana DEQ using SCS C-factor tables (Brooks et al. 1997). C-factors are intended to be conservatively representative of conditions in the Shields Valley.

P – Management practices factor. This factor was set to 1, as consultation with the NRCS State Agronomist suggests that this value is the most appropriate representation of current management practices in the Shields River Watershed (i.e. no use of contour plowing, terracing, etc).

Method
An appropriate grid for each factors' values was created, giving full and appropriate consideration to proper stream network delineation, grid cell resolution, etc. A computer model was built using ArcView Model Builder to derive the five factors from model inputs, multiply the five factors, and arrive at a predicted sediment production for each grid cell. The model also derived a sediment delivery ratio for each cell, and reduced the predicted sediment production by that factor to estimate sediment delivered to the stream network.

Specific parameterization of the USLE factors was performed as follows:

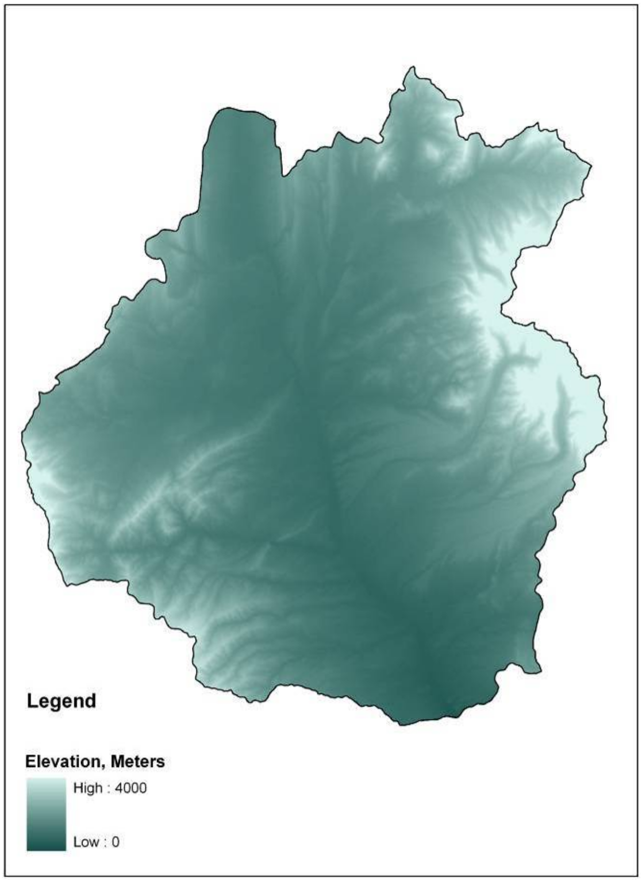

Figure E-1. Digital Elevation Model (DEM) of the Shields River Watershed, Prepared for Hydrologic Analysis

Shields DEM

The DEM for the Shields River Watershed was the foundation for developing the LS factor, for defining the extent of the bounds of the analysis area (the Shields River Watershed), and for delineating the area within the outer bounds of the analysis for which the USLE model is not valid (i.e. the concentrated flow channels of the stream network). The USGS 30m DEM (level 2) for the Shields was used for these analyses. First the DEM was interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of Shields River watershed streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m was then subjected to standard hydrologic preprocessing, including the filling of sinks to create a positive drainage condition for all areas of the watershed.

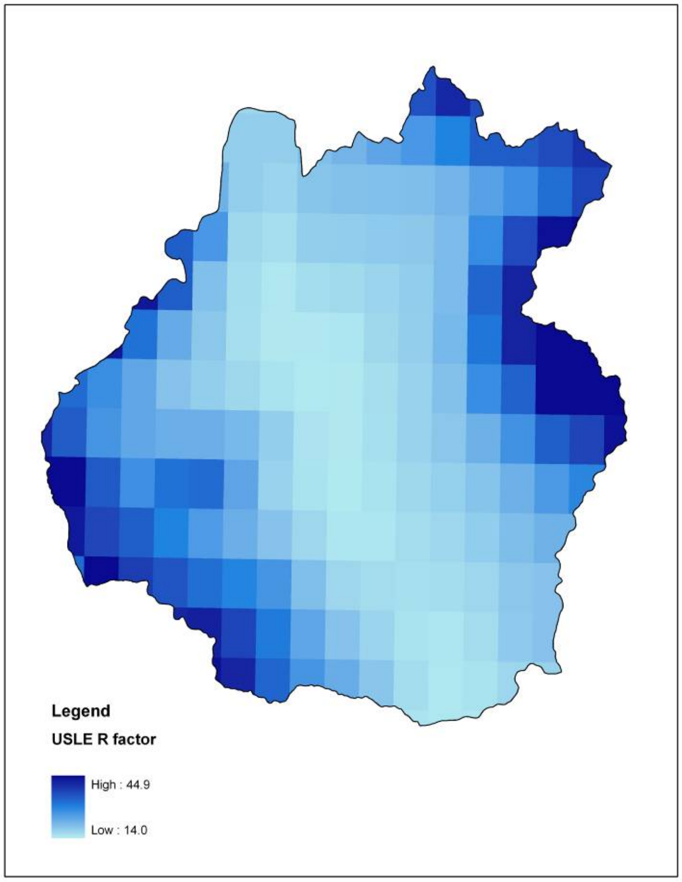

Figure E-2. ULSE R Factor for the Shields Watershed

R-Factor

The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service (SCAS) of Oregon State University at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was reprojected to Montana State Plane Coordinates (NAD83, meters), resampled to a 10m analytic cell size and clipped to the extent of the Shields Watershed, to match the project's standard grid definition.

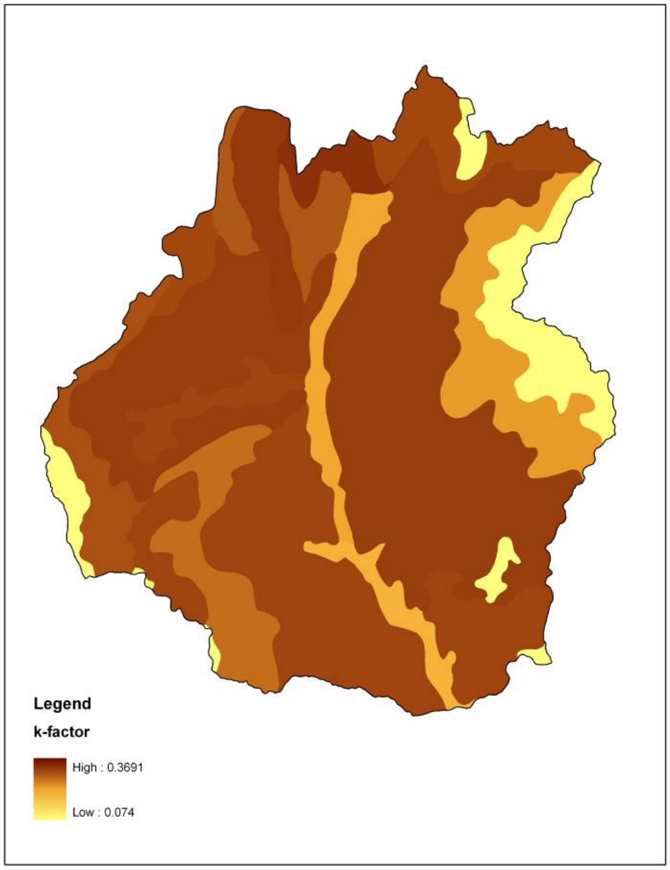

Figure E-3. ULSE K factor for the Shields Watershed.

K-Factor
The soil erodibility factor grid was compiled from 1:250K STATSGO data, as published by the NRCS. STATSGO database tables were queried to calculate a component weighted K value for all surface layers, which was then summarized by individual map unit. The map unit K values were then joined to a GIS polygon coverage of the STATSGO map units, and the polygon coverage was converted to a 10m analytic grid for use in this analysis.

LS- Factor
The equation used for calculating the slope length and slope factor was that given in the updated definition of USLE, as published in USDA handbook #537:

$$LS = (\lambda/72.6)^{m} (65.41 \sin^{2}\theta + 4.56 \sin\theta + 0.065)$$

Where:

λ = slope length in feet. This value was determined by applying GIS based surface analysis procedures to the Shields watershed DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters. In accordance with research that indicates that, in practice, the slope length rarely exceeds 400 ft, λ was limited to that maximum value.

θ = cell slope cell slope as calculated by GIS based surface analysis procedures from the Shields watershed DEM

m = 0.5 if percent slope of the cell >= 5
= 0.4 if percent slope of the cell >= 3.5 AND < 5
= 0.3 if percent slope of the cell >= 1 AND < 3.5
= 0.2 if percent slope of the cell < 1

The LS factor grid was calculated from individual grids computed for each of these sub factors, using a simple ArcView Model Builder script.

C-Factor

The cover management factor of the USLE reflects the varying degree of erosion protection that results from different cover types. It integrates a number of factors including vegetative cover, plant litter, soil surface, and land management. For the purpose of this study, the C-factor is the only USLE parameter that can be altered by the influence of human activity. Based on this, C-factors were estimated for the existing condition and improved management scenarios (**Table E-2**). The C-factor change for agricultural cover types between management scenarios corresponds to increases in the percent of land cover that are achievable through the application of various best management practices (**Table E-3**). For natural sources (i.e. bare rock, deciduous forest, and evergreen forest), the C-factor is the same for both scenarios. A C-factor slightly higher than deciduous/evergreen forest was used for logged areas because logging intensity within the watershed is low and because practices, such as riparian clearcutting, that tend to produce high sediment yields have not been used since at least 1991, when the Montana SMZ Law was enacted. Additionally, the USLE model is intended to reflect long-term average sediment yield, and while a sediment pulse typically occurs in the first year after logging, sediment production after the first year rapidly declines (Rice et al. 1972; Elliot and Robichaud 2001; Elliot 2006). The logging C-factor is the same for both management scenarios to indicate that logging will continue sporadically on public and private land within the watershed and will produce sediment at a rate slightly higher than an undisturbed forest. This is not intended to imply that additional best management practices beyond those in the SMZ law should not be used for logging activities.

C-factors were defined spatially through use of a modified version of the Anderson land cover classification (1976) and the 1992 30m Landsat Thematic Mapper (TM) multi-spectral imaging (NLDC, 1992) (**Figure E-4**). C-factor values were assigned globally to each land type and range from 0.001 to 1.0. These data were reprojected to Montana State plane projection/coordinate system and resampled to the standard 10m grid. No field efforts were initiated as part of this study to refine C-factor estimation for the watershed.

Table E-2. Shields River C-Factor; Existing and Improved Management Conditions

NLCD Code	Description	C-Factor	
		Existing Condition	Improved Management Condition
31	Bare Rock/Sand/Clay	0.001	0.001
41	Deciduous Forest	0.003	0.003
42	Evergreen Forest	0.003	0.003
51	Shrubland	0.046	0.031
71	Grasslands Herbaceous	0.042	0.035
81	Pasture /Hay	0.020	0.013
83	Small Grains	0.240	0.015
84	Fallow	0.440	0.120
N/A	Logging	0.006	0.006

Table E-3. Changes in Percent Ground Cover for Agricultural Land Cover Types between Existing and Improved Management Condition.

Land Cover	Existing % ground cover	Improved % ground cover
Shrubland	55	65
Grasslands Herbaceous	55	65
Pasture /Hay	65	75
Small Grains	20	40
Fallow	5	35

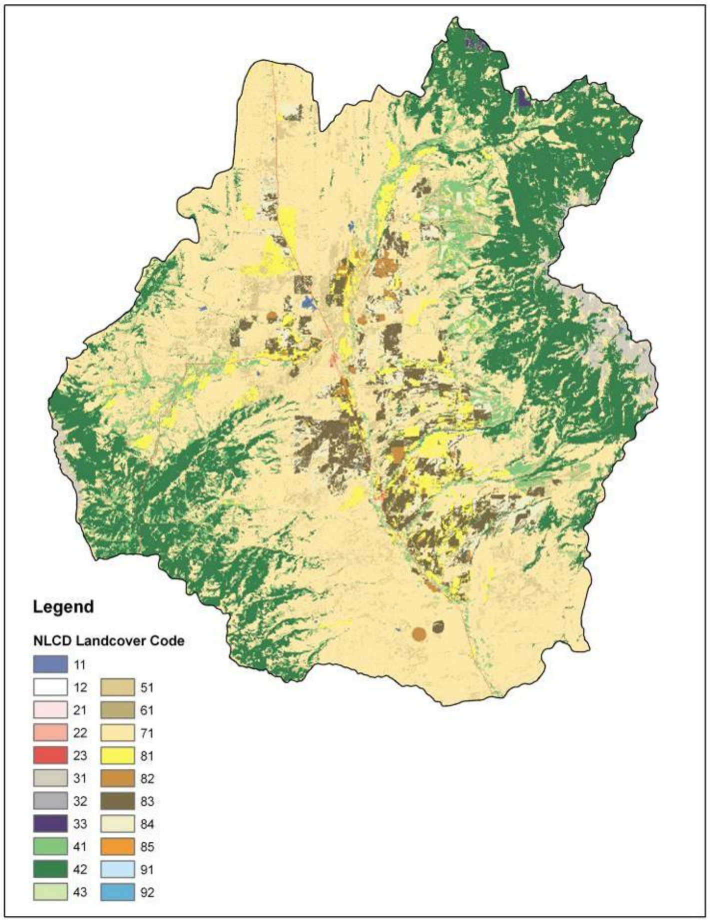

Figure E-4. NLCD Landcover for the Shields Watershed

<u>NLCD – Landcover</u>
In general, the land use classification of the NLCD was accepted as is, without ground truthing of original results or correction of changes over the time since the NLCD image was taken. Given that we are looking for watershed and subwatershed scale effects, this was considered to be a reasonable assumption given the relative simplicity of the land use mix in the Shields Valley, and the relative stability of that land use over the 14 years since the Landsat image that the NLCD is based on was shot. One adjustment was made to the NLCD, however. That adjustment was to quantify the amount of logging that has occurred since 1992, and to also identify areas that are reforesting over that same period. As with other land uses in the valley, logging is a stable land use, but it is a land use that causes a land cover change that may effect sediment production.

Adjustment for logging and reforestation was accomplished by comparing the 1992 NLCD grid for the Shields Watershed with the 2005 NAIP aerial photography. Areas which were coded as a forest type (41 or 42) on the NLCD were recoded to 'logged' if:

- They appeared to be otherwise (typically bare ground, grassland, or shrubland) on the NAIP photos, and

- There were indications of indicated logging activity (proximity to forest or logging roads, appearance of stands, etc).

Sediment Delivery Ratio

A SDR factor was created for each grid cell, based on the relationship between the distance from the delivery point to the stream established by Dube, Megahan & McCalmon in their development of the WARSEM road sediment model for the State of Washington. This relationship was developed by integrating the results of several previous studies (principally those of Megehan and Ketchison) which examined sediment delivery to streams downslope of forest roads. They found that the proportion of sediment production that is ultimately delivered to streams declines with distance from the stream (**Table E-4**) with the balance of the sediment being deposited between the point of production and the stream. We believe the use of this relationship to develop a SDR for a USLE based model is a conservative (i.e. tending toward the high end of the range of reasonable values) estimate of sediment delivery from hillslope erosion, especially in light of the fact that the USLE methodology does not account for gully erosion. The SDR factor was applied to the results of the USLE model to estimate sediment delivered from hill slope sources, by calculating the distance from each cell to the nearest stream channel, and multiplying the sediment production of that cell by the corresponding distance based percentage of delivery.

Table E-4. The Percent of Sediment Delivered by Distance from a Water Body

Distance from Culvert (ft)	Percent of Total Eroded Sediment Delivered
0	100
35	70
70	50
105	35
140	25
175	18
210	10
245	4
280	3
315	2
350	1

Although the SDR factor accounts for the distance of sediment production cells from the stream channel, it does not account for riparian condition and the ability of riparian vegetation to filter out sediment and prevent it from entering the stream. Depending on the vegetation type and buffer width, healthy riparian buffers can remove anywhere from 50-90% of sediment (Castelle and Johnson 2000; Hook 2003; DEQ 2007). Therefore, the USLE model used for source assessment may have overestimated existing loads and underestimated potential reductions due to hillslope erosion.

Results

Figures E-5 and E-6 present the USLE based hillslope model's prediction of existing and potential conditions graphically for the entire Shields River watershed. **Table E-5** contains the estimated existing and potential sediment load from hillslope erosion for each 6^{th} code HUC and the entire Shields River watershed, and it also contains loads normalized by the contributing watershed area. **Table E-6** contains the estimated existing and potential sediment load from hillslope erosion for each 6th code HUC and the Shields River watershed broken out by land cover type.

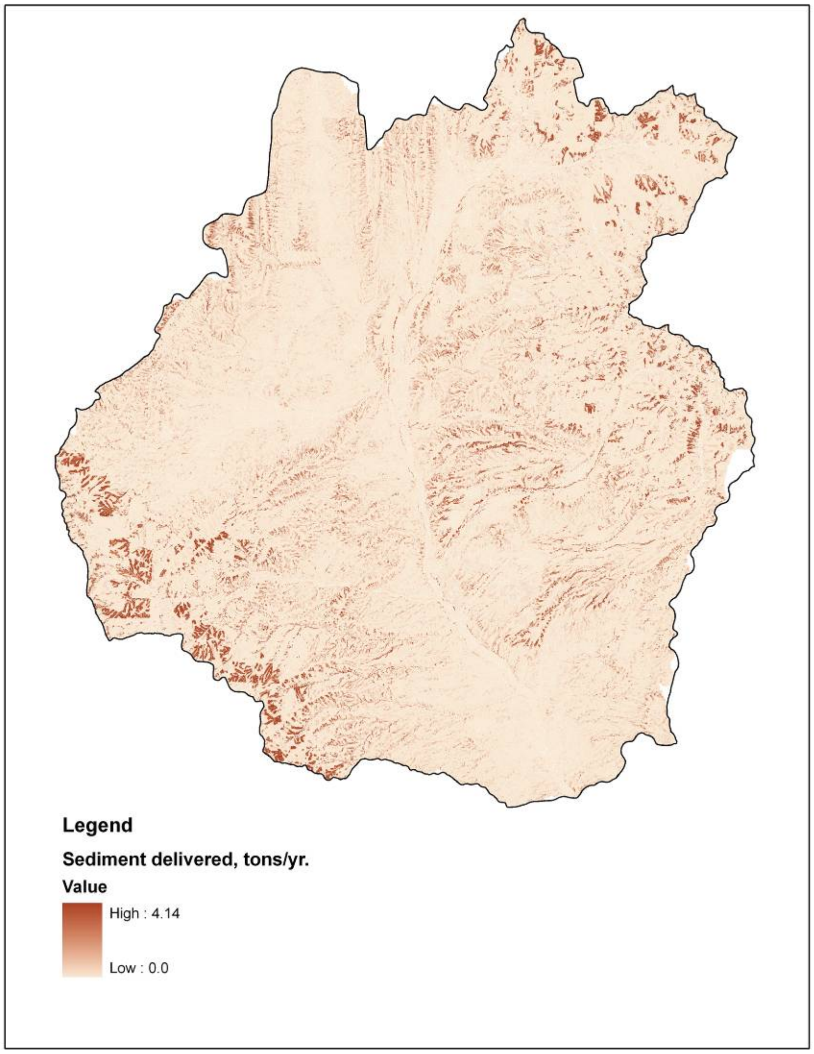

Figure E-5. Estimated Sediment Delivery from Hill Slopes, Existing Conditions

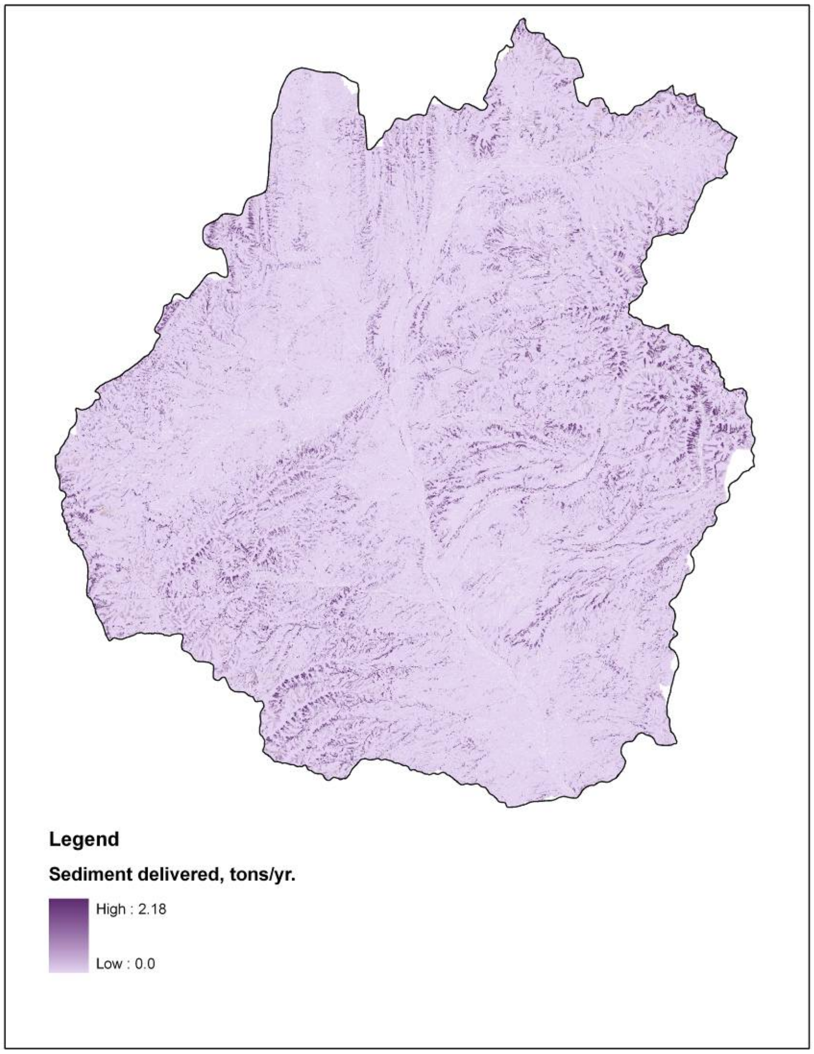

Figure E-6. Estimated Sediment Delivery from Hill Slopes, BMP Conditions

Table E-5. Total and Normalized Existing and Potential Sediment Loads from Upland Erosion for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
Adair Creek	13387	2100	1700	0.157	0.127
Bangtail Creek	8613	5600	2800	0.648	0.319
Canyon Creek	14004	5900	2700	0.421	0.193
Carrol Creek	19168	4600	2500	0.239	0.131
Cottonwood Creek East	23497	10700	6800	0.455	0.288
Cottonwood Creek West	20766	4600	3600	0.223	0.171
Daisy Dean Creek	9551	2900	1900	0.306	0.201
Dry Creek	13058	1500	1200	0.119	0.090
Elk Creek	16912	4200	1800	0.249	0.107
Falls Creek	16531	3600	2100	0.217	0.128
Horse Creek	24839	8700	4600	0.350	0.187

Table E-5. Total and Normalized Existing and Potential Sediment Loads from Upland Erosion for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
Lower Brackett Creek	14322	3200	2600	0.226	0.182
Lower Flathead Creek	20238	2500	1900	0.124	0.092
Lower Shields River-Chicken Creek	24117	6900	1900	0.285	0.078
Lower Shields River-Crazyhead Creek	21462	2300	1900	0.109	0.088
Meadows Creek	15909	4200	2200	0.265	0.137
Middle Shields River-Antelope Creek	35868	12900	4900	0.359	0.135
Middle Shields River-Spring Creek	9729	1900	500	0.191	0.053
Muddy Creek	13461	2800	2100	0.208	0.158
Porquepine Creek	15842	3200	1700	0.203	0.106
Potter Creek	**37476**	**5700**	**3700**	**0.151**	**0.100**
Rock Creek	33877	13700	10200	0.404	0.302
Upper Brackett Creek	27582	15400	6800	0.558	0.247
Upper Flathead Creek	14638	3100	2500	0.214	0.174
Upper Shields River-Antelope Creek	15179	2700	1900	0.178	0.123
Upper Shields River-Bennett Creek	31894	10600	5100	0.331	0.159
Upper Shields River-Kavanaugh Creek	14567	2400	1900	0.165	0.132
Willow Creek	19872	8800	5500	0.444	0.278
Total Shields Watershed	**546359**	**157000**	**89000**	**0.287**	**0.163**

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Adair Creek	Deciduous Forest	<10	<10
Adair Creek	Evergreen Forest	10	10
Adair Creek	Shrubland	280	190
Adair Creek	Grasslands/Herbaceous	1800	1500
Adair Creek	Small Grains	<10	0
Bangtail Creek	Bare Rock/Sand/Clay	<10	<10
Bangtail Creek	Deciduous Forest	20	20
Bangtail Creek	Evergreen Forest	210	210
Bangtail Creek	Shrubland	630	380
Bangtail Creek	Grasslands/Herbaceous	4630	2070
Bangtail Creek	Small Grains	20	<10
Bangtail Creek	Fallow	<10	0
Bangtail Creek	Logged	80	80
Canyon Creek	Deciduous Forest	20	20
Canyon Creek	Evergreen Forest	250	250
Canyon Creek	Shrubland	650	400
Canyon Creek	Grasslands/Herbaceous	4760	1900
Canyon Creek	Small Grains	80	<10
Canyon Creek	Logged	120	120
Carrol Creek	Commercial/Industrial/Transportation	<10	<10
Carrol Creek	Bare Rock/Sand/Clay	40	40
Carrol Creek	Deciduous Forest	30	30
Carrol Creek	Evergreen Forest	370	370
Carrol Creek	Shrubland	670	350
Carrol Creek	Grasslands/Herbaceous	3230	1490
Carrol Creek	Pasture/Hay	30	20
Carrol Creek	Logged	220	220
Cottonwood Creek East	Bare Rock/Sand/Clay	140	140
Cottonwood Creek East	Deciduous Forest	40	40
Cottonwood Creek East	Evergreen Forest	960	960
Cottonwood Creek East	Shrubland	1260	840
Cottonwood Creek East	Grasslands/Herbaceous	5150	4210
Cottonwood Creek East	Pasture/Hay	90	60
Cottonwood Creek East	Small Grains	1480	90
Cottonwood Creek East	Fallow	1570	430
Cottonwood Creek East	Logged	10	10
Cottonwood Creek West	Deciduous Forest	10	10
Cottonwood Creek West	Evergreen Forest	30	30
Cottonwood Creek West	Shrubland	440	300
Cottonwood Creek West	Grasslands/Herbaceous	3770	3140
Cottonwood Creek West	Pasture/Hay	40	20
Cottonwood Creek West	Small Grains	180	10
Cottonwood Creek West	Fallow	170	50
Daisy Dean Creek	Bare Rock/Sand/Clay	<10	<10
Daisy Dean Creek	Deciduous Forest	10	10
Daisy Dean Creek	Evergreen Forest	90	90

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Daisy Dean Creek	Shrubland	370	250
Daisy Dean Creek	Grasslands/Herbaceous	1620	1350
Daisy Dean Creek	Pasture/Hay	10	<10
Daisy Dean Creek	Small Grains	60	<10
Daisy Dean Creek	Fallow	760	210
Dry Creek	Deciduous Forest	20	20
Dry Creek	Evergreen Forest	40	40
Dry Creek	Shrubland	300	200
Dry Creek	Grasslands/Herbaceous	1070	890
Dry Creek	Pasture/Hay	<10	<10
Dry Creek	Small Grains	60	<10
Dry Creek	Fallow	60	20
Elk Creek	Bare Rock/Sand/Clay	<10	<10
Elk Creek	Deciduous Forest	20	20
Elk Creek	Evergreen Forest	230	230
Elk Creek	Shrubland	300	200
Elk Creek	Grasslands/Herbaceous	870	720
Elk Creek	Pasture/Hay	20	10
Elk Creek	Row Crops	<10	<10
Elk Creek	Small Grains	620	40
Elk Creek	Fallow	2140	590
Falls Creek	Deciduous Forest	10	10
Falls Creek	Evergreen Forest	80	80
Falls Creek	Shrubland	470	320
Falls Creek	Grasslands/Herbaceous	1630	1360
Falls Creek	Pasture/Hay	10	<10
Falls Creek	Small Grains	220	10
Falls Creek	Fallow	1160	320
Horse Creek	Bare Rock/Sand/Clay	<10	<10
Horse Creek	Deciduous Forest	50	50
Horse Creek	Evergreen Forest	410	410
Horse Creek	Shrubland	710	470
Horse Creek	Grasslands/Herbaceous	3500	2810
Horse Creek	Pasture/Hay	70	50
Horse Creek	Small Grains	1150	70
Horse Creek	Fallow	2770	760
Horse Creek	Logged	30	30
Lower Brackett Creek	Deciduous Forest	10	10
Lower Brackett Creek	Evergreen Forest	50	50
Lower Brackett Creek	Shrubland	540	360
Lower Brackett Creek	Grasslands/Herbaceous	2600	2170
Lower Brackett Creek	Pasture/Hay	<10	<10
Lower Brackett Creek	Small Grains	30	<10
Lower Brackett Creek	Fallow	<10	<10
Lower Flathead Creek	Deciduous Forest	20	20
Lower Flathead Creek	Evergreen Forest	170	170
Lower Flathead Creek	Mixed Forest	0	0

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Lower Flathead Creek	Shrubland	600	410
Lower Flathead Creek	Grasslands/Herbaceous	1480	1200
Lower Flathead Creek	Pasture/Hay	50	30
Lower Flathead Creek	Small Grains	150	<10
Lower Flathead Creek	Fallow	40	10
Lower Shields River-Chicken Creek	Deciduous Forest	<10	<10
Lower Shields River-Chicken Creek	Evergreen Forest	10	10
Lower Shields River-Chicken Creek	Shrubland	200	140
Lower Shields River-Chicken Creek	Grasslands/Herbaceous	750	630
Lower Shields River-Chicken Creek	Pasture/Hay	70	40
Lower Shields River-Chicken Creek	Small Grains	2550	160
Lower Shields River-Chicken Creek	Fallow	3300	900
Lower Shields River-Crazyhead Creek	Deciduous Forest	<10	<10
Lower Shields River-Crazyhead Creek	Evergreen Forest	<10	<10
Lower Shields River-Crazyhead Creek	Shrubland	250	170
Lower Shields River-Crazyhead Creek	Grasslands/Herbaceous	2060	1720
Lower Shields River-Crazyhead Creek	Small Grains	30	<10
Lower Shields River-Crazyhead Creek	Fallow	<10	<10
Meadows Creek	Bare Rock/Sand/Clay	<10	<10
Meadows Creek	Deciduous Forest	30	30
Meadows Creek	Evergreen Forest	580	580
Meadows Creek	Shrubland	650	310
Meadows Creek	Grasslands/Herbaceous	2830	1140
Meadows Creek	Logged	130	130
Middle Shields River-Antelope Creek	Deciduous Forest	30	30
Middle Shields River-Antelope Creek	Evergreen Forest	100	100
Middle Shields River-Antelope Creek	Shrubland	670	450
Middle Shields River-Antelope Creek	Grasslands/Herbaceous	3160	2630
Middle Shields River-Antelope Creek	Pasture/Hay	70	50
Middle Shields River-Antelope Creek	Row Crops	<10	<10
Middle Shields River-Antelope Creek	Small Grains	4050	250
Middle Shields River-Antelope Creek	Fallow	4790	1310
Middle Shields River-Spring Creek	Deciduous Forest	<10	<10
Middle Shields River-Spring Creek	Shrubland	60	40
Middle Shields River-Spring Creek	Grasslands/Herbaceous	210	170
Middle Shields River-Spring Creek	Pasture/Hay	50	30
Middle Shields River-Spring Creek	Small Grains	730	50
Middle Shields River-Spring Creek	Fallow	810	220
Muddy Creek	Deciduous Forest	20	20
Muddy Creek	Evergreen Forest	70	70
Muddy Creek	Shrubland	350	240
Muddy Creek	Grasslands/Herbaceous	2100	1750
Muddy Creek	Pasture/Hay	<10	<10
Muddy Creek	Small Grains	140	<10
Muddy Creek	Fallow	110	30
Porquepine Creek	Deciduous Forest	30	30
Porquepine Creek	Evergreen Forest	100	100

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Porquepine Creek	Shrubland	480	320
Porquepine Creek	Grasslands/Herbaceous	1010	840
Porquepine Creek	Pasture/Hay	30	20
Porquepine Creek	Small Grains	280	20
Porquepine Creek	Fallow	1290	350
Potter Creek	**Deciduous Forest**	<10	<10
Potter Creek	**Evergreen Forest**	**10**	**10**
Potter Creek	**Shrubland**	**650**	**440**
Potter Creek	**Grasslands/Herbaceous**	**3530**	**2940**
Potter Creek	**Pasture/Hay**	**50**	**30**
Potter Creek	**Small Grains**	**400**	**30**
Potter Creek	**Fallow**	**1030**	**280**
Rock Creek	Bare Rock/Sand/Clay	250	250
Rock Creek	Deciduous Forest	70	70
Rock Creek	Evergreen Forest	1120	1120
Rock Creek	Shrubland	2400	1620
Rock Creek	Grasslands/Herbaceous	8310	6830
Rock Creek	Pasture/Hay	40	30
Rock Creek	Small Grains	430	30
Rock Creek	Fallow	1030	280
Rock Creek	Logged	20	20
Upper Brackett Creek	Commercial/Industrial/Transportation	<10	<10
Upper Brackett Creek	Bare Rock/Sand/Clay	30	30
Upper Brackett Creek	Deciduous Forest	170	170
Upper Brackett Creek	Evergreen Forest	1050	1050
Upper Brackett Creek	Shrubland	2600	1360
Upper Brackett Creek	Grasslands/Herbaceous	11040	3740
Upper Brackett Creek	Pasture/Hay	<10	<10
Upper Brackett Creek	Logged	480	480
Upper Flathead Creek	Bare Rock/Sand/Clay	40	40
Upper Flathead Creek	Deciduous Forest	30	30
Upper Flathead Creek	Evergreen Forest	160	160
Upper Flathead Creek	Shrubland	510	340
Upper Flathead Creek	Grasslands/Herbaceous	2240	1820
Upper Flathead Creek	Pasture/Hay	10	<10
Upper Flathead Creek	Logged	160	160
Upper Shields River-Antelope Creek	Deciduous Forest	<10	<10
Upper Shields River-Antelope Creek	Evergreen Forest	<10	<10
Upper Shields River-Antelope Creek	Shrubland	360	250
Upper Shields River-Antelope Creek	Grasslands/Herbaceous	1870	1560
Upper Shields River-Antelope Creek	Pasture/Hay	20	20
Upper Shields River-Antelope Creek	Row Crops	<10	<10
Upper Shields River-Antelope Creek	Small Grains	360	20
Upper Shields River-Antelope Creek	Fallow	80	20
Upper Shields River-Bennett Creek	Bare Rock/Sand/Clay	60	60
Upper Shields River-Bennett Creek	Deciduous Forest	20	20
Upper Shields River-Bennett Creek	Evergreen Forest	1560	1560

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Upper Shields River-Bennett Creek	Shrubland	1030	530
Upper Shields River-Bennett Creek	Grasslands/Herbaceous	7660	2650
Upper Shields River-Bennett Creek	Logged	250	250
Upper Shields River-Kavanaugh Creek	Deciduous Forest	20	20
Upper Shields River-Kavanaugh Creek	Evergreen Forest	70	70
Upper Shields River-Kavanaugh Creek	Shrubland	330	220
Upper Shields River-Kavanaugh Creek	Grasslands/Herbaceous	1890	1570
Upper Shields River-Kavanaugh Creek	Pasture/Hay	30	20
Upper Shields River-Kavanaugh Creek	Small Grains	10	<10
Upper Shields River-Kavanaugh Creek	Fallow	60	20
Willow Creek	Bare Rock/Sand/Clay	<10	<10
Willow Creek	Deciduous Forest	30	30
Willow Creek	Evergreen Forest	340	340
Willow Creek	Shrubland	1070	670
Willow Creek	Grasslands/Herbaceous	7160	4280
Willow Creek	Pasture/Hay	10	<10
Willow Creek	Small Grains	10	<10
Willow Creek	Fallow	<10	<10
Willow Creek	Logged	190	190
Shields Watershed	**Bare Rock/Sand/Clay**	**570**	**570**
Shields Watershed	**Deciduous Forest**	**730**	**730**
Shields Watershed	**Evergreen Forest**	**8090**	**8090**
Shields Watershed	**Shrubland**	**18850**	**11750**
Shields Watershed	**Grasslands/Herbaceous**	**91920**	**59060**
Shields Watershed	**Pasture/Hay**	**720**	**470**
Shields Watershed	**Row Crops**	<10	<10
Shields Watershed	**Small Grains**	**13040**	**820**
Shields Watershed	**Fallow**	**21190**	**5780**
Shields Watershed	**Logged**	**1680**	**1680**

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